R E P O R T  R E S U M E S

ED 015 863 RE 001 078

VISION AND READING ABILITY.

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PUB DATE OCT 67

EDRS PRICE MF-$0.25 HC-$1.44 34P.

DESCRIPTORS- *VISUALLY HANDICAPPED, *PERCEPTUAL MOTOR LEARNING, READING DIFFICULTY, *READING ABILITY, VISION TESTS, CEREBRAL DOMINANCE, AMETROPIA, HYPEROPIA, STEREOPSIS, VISUAL ACUITY, HETEROPHORIA, MYOPIA, ANISEIKONIA, HETEROTROPIA, INDIANA UNIVERSITY.

SIGNIFICANT RESEARCH ON THE PHYSIOLOGICAL AND FUNCTIONAL ASPECTS OF VISION AND READING DISABILITY IS SURVEYED. CONCLUSIONS BASED ON THE LITERATURE IN THE FIELD ARE DISCUSSED. A BIBLIOGRAPHY OF 70 REFERENCES AND A GLOSSARY OF TERMS ARE APPENDED. A TABLE SUMMARIZING REFRACTIVE ERRORS AND EYE DEFECTS CONTRIBUTING TO READING DISABILITY IS INCLUDED. (MC)

# OCCASIONAL PAPERS IN READING

INDIANA UNIVERSITY SCHOOL OF EDUCATION





## VISION

## and

## READING ABILITY

Charles T. Mangrum
School of Education
Indiana University
October, 1967

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Volume I

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Occasional Papers in Reading is issued on a non-regular basis eight to twelve times per year. Papers can deal with any aspect of reading including articles describing research projects, theoretical speculation on reading, reports and evaluations on innovative program developments, reviews of tests and instructional materials, annotated or analytical bibliographies, and other general or specialized papers of current interest to the reading researcher or practitioner. Manuscripts for inclusion are invited and should be submitted to Dr. Leo Fay, Editor, Occasional Papers in Reading, School of Education, Indiana University, 220 Pine Hall, Bloomington, Ind. 47401. All submitted papers are evaluated by the Editorial Advisory Board, Dr. E. G. Summers, Chairman. Copies of papers in the series can be obtained by writing to the Editor.

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## INTRODUCTION

How reading is defined will influence how it will be taught. A narrow definition encourages the development of panaceas while an encompassing definition often is rejected by practitioners as unworkable or vague. It is truly easier to understand the simple, well defined, and highly structured reading program while its counterpart, which attempts to operate within a unifying theory, is more difficult to understand.

If progress is to be made in understanding the reading process, all concomitants of behavior related to that process must be investigated. Rather than being satisfied with an oversimplified definition of reading such as "talk writ down," a definition which includes those aspects of human behavior brought into operation when reading takes place must be developed.

Certain physiological factors have been identified as being related to the reading process. Although there is disagreement as to the relative weight assigned to the physiological factors, as there is disagreement within this area over the assignment of weights, there seems to be a general agreement that reading development can be negatively influenced by physiological factors.

This paper is concerned with only one of the areas under physiological factors related to reading. The area of vision has been attributed with providing the adult with as much as 80 per cent of his accumulated knowledge. (27:1) It would seem that any factor of such importance should be included in a discussion of reading. The purpose of this paper is to review the research which explores the relationship between visual defects and reading ability.

## STUDIES SUGGESTING A RELATIONSHIP BETWEEN VISUAL DEFECTS AND READING ABILITY

It seems logical to suggest that visual defects might influence the reading performance of children. Such has been the finding of a number of researchers. Certain researchers have noted statistical or frequency relationships between separate visual defects and reading ability while other researchers have noted similar relationships between total visual defects and reading ability.

Park and Burri (45:290-9) examined the relationship of various eye conditions and reading achievement in an attempt to determine the degree to which certain visual conditions influenced reading achievement. The investigators found that good readers have fewer than average visual deficiencies than poor readers for their chronological and mental age groups. Poor readers, conversely, tended to have more than the average number of visual deficiencies for their corresponding chronological and mental age groups. A correlation of .465 was reported between visual deficiencies measured in this study (acuity, refractive error, fusion, stereopsis, phorias, and ductions)* and reading proficiency.

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*Note glossary of terms in Appendix I. The writer wishes to thank Dr. Tony Adams, O.D., Indiana University, for his assistance in developing the glossary.

Dearborn and Anderson (13:559-77) explored the relationship of aniseikonia to reading disability with similar groups of 100 subjects whose chronological ages ranged from nine to young adult. The investigators found 51 per cent of the experimental group evidenced aniseikonia in excess of one per cent compared to 23 per cent in the control group. The between group difference was sufficient to be statistically significant at the .001 level. The researchers noted that aniseikonia in excess of one per cent was normally considered sufficient for visual disturbance while aniseikonia under one per cent was usually not critical. Individual differences, however, among cases often required treatment for small disturbances as low as .5 per cent. The investigators attributed the large number of identified cases of aniseikonia to their measurements at the reading distance rather than at 20 feet. It was concluded that aniseikonia was one of the major factors in "causation and persistence of disability in reading." (13:577)

According to Dearborn and Anderson, aniseikonia affected the child's ability to fuse images from both eyes. This lack of fusion ability caused the child to use extra energy when attempting to compensate for his inability. The use of extra energy to force fusion caused ocular and general body fatigue which resulted in shorter periods of task concentration. Aniseikonia was also found to affect peripheral span and length of fixation, both deemed necessary for effective reading.

Betts (3:163-4) from his clinical investigations of children and the development of the Betts Ready To Read Tests concluded that many reading problems were directly related to a lack of binocular coordination and fusion. He found approximately ninety per cent of an unreported figure of severely disabled readers characterized visually be "faculty binocular coordination and astigmatism." (3:171)

Spache and Tillman (61:101-9) analyzed the visual profiles of 215 clinic subjects, 114 diagnosed as reading retardates, 101 as nonretardates. The researchers found that the retardates scored significantly lower (.05 level) than the nonretardates "in acuity in the left eye at near-point." A significantly larger (.01 level) percentage of retardates had "acuity differences between the two eyes," and a significant number of retardates failed visual acuity with both eyes at near" point. (61:107-8) The researchers concluded that their study supported the general theory that "fusion difficulties are strongly related to reading difficulty" (61:108) because the three significant differences supported each other and indicated "a weakness in binocular acuity at near-point among retarded readers." (61:107-9) However, retarded and nonretarded readers tended to have profiles which were more similar than different.

Spache and Tillman (61:102-3) reviewed a study conducted by Hurst (34) with two thousand school children. Hurst concluded that children with reading difficulties demonstrated singularly or in combination a lack of convergence ability or continued convergence for task performance over a period of time.

Good (30:115-21) investigated the relationship between "muscle fusion power and reading disability" with matched groups of 25 elementary school children. The experimental group consisted of reading disability cases while the control group consisted of able readers. Poor readers were found to have the least duction power while average readers possessed good duction power. Although no data was provided, after correction of ocular defects, the disabled readers were reported to have made marked improvement. Good concluded, "Adduction and abduction weaknesses definitely accompany difficulties in learning to read." (30:120)

Eames (15:1-5) compared a group of 100 disabled readers with a corresponding group of 143 unselected school children to determine the frequency with which certain visual deficiencies occurred among the two groups. Eames found that disabled readers evidenced a greater percentage of exophoria at near, farsightedness, anomalies of eyedness, mixed dominance, and low fusion difficulties than the unselected population.

Witty and Kopel (69:222-30) cited a study by Selzer (53) reported in the Harvard Monograph in Education wherein the researcher concluded, "Ninety per cent of thirty-three reading disability cases evinced eye-muscle imbalance, whereas only nine of one hundred unselected children showed the defect." (69:223)

Stromberg (63:70-8) reviewed a research study conducted by Fendricks (24) in which the reporter was cited as concluding, "Errors of the refractive type are probably the cause of a large proportion of reading deficiencies." (63:70-1)

Gillet (29:178-84) reported a higher than expected incidence of farsightedness and mixed dominance for nonreaders. Grade levels, ages, and other identifying data were not included in the report.

Spache and Tillman (61:101-3) reviewed a study by Kelly (38) who examined separate groups of 100 first, fifth, and ninth grade children annually over a four-year period using the telebinocular tests. Spache cited the following conclusions from Kelly's study: (61:101-2)

Fusion. "Good readers tend to have efficient binocular vision or are one-eyed readers."

Stereopsis. "Good depth scores are associated with good fusion, good visual acuity and either good lateral imbalance scores or over convergence." Stereopsis is not important for reading other than as an indicator of deficiencies in other visual areas.

Phorias. Poor convergence and exophoria at near point is accompanied by poor fusion, low depth scores, and poor near and far acuity. Esophoria at far and near and exophoria were found to be related to poor reading scores. Myoptic children with phorias do as well as normal children while hyperopes with phorias at far point have poor reading scores.

Kephart (40:794-799) reported on the visual status of 2,200 school children with the Ortho-Rater. Kephart concluded that there were a large number of school children with inadequate visual skills. His research indicated a relationship between visual skills and school achievement. Visual skills tended to improve with increased school achievement. Significantly more good than poor readers were able to meet accepted visual standards on the Ortho-Rater.

Crider (11:295-7) explored the relationship between eye muscle imbalance and visual fusion, alternating vision and ocular dominance. Crider found that 75.24 per cent of the pupils with a left eye imbalance (N=105) tended to read digits with their right eye, while 84.24 per cent of the pupils with a right eye imbalance (N-38) tended to read digits with their left eye. Crider cited research by Selzer (53) and concurred with the latter on his finding that visual fusion, alternating vision, ocular dominance and muscle imbalance are all related in some way.

Farris (23:58-60) studied the relationship of visual defects in isolation, collectively, and after correction to reading achievement with 768 seventh grade children. The sample consisted of two groups equated for intelligence and chronological age but who were different in visual functioning. The researchers found hyperopia and strabismus to be associated with poor reading progress. Myopia and myopic astigmatism were found to be associated with average reading progress. Eye strain was found to correlate significantly with hyperopia which suggested that greater strain was being put on the nervous system for proper adjustment by the hyperopic eye. Myopic eyes were found to adjust to the reading task with less strain and muscle exertion than the emmetropic eyes. Monocular vision was found to be more efficient for reading than binocular vision with inadequate coordination. Myopia, hyperopia, and strabismus were the only eye defects concluded to have any significant relationship to reading progress.

Farris further concluded that when all eye defects were considered together, the defective group made slightly better progress than the normal group. The reading superiority of the defective group was attributable to the inclusion of reading scores for the myopics. Correction of hyperopia and strabismus eye defects brought about substantial improvement in reading of the disabled readers group over a similar group with uncorrected vision exposed to similar treatment. Myopics with corrected vision did less well than myopics with uncorrected vision. According to the researcher, the findings demonstrated the inadequacies of such tests as the Snellen. The Snellen test emphasized retinal activity at 20 feet while ignoring muscular functions of the eyes shown to be sources of discomfort which affect reading success. (23:58-60)

Eames (16:132) analyzed the eye defects of unselected fifth grade children with mental ages of 6.7 to 13.0. Eye examinations were conducted by a trained oculist who also provided the necessary corrections or training. The Kuhlman-Anderson Test of Intelligence was administered to

obtain I.Q. scores. Children were grouped according to eye defect and I.Q. Eames compared the reading gains before and after visual correction or training. Eames concluded that there was no significant difference between reading growth before and after amelioration for groups with eye difficulties and below 90 I.Q.'s, no eye difficulties and 90 or above I.Q.'s, or the whole group. Eames did note a six-month difference in reading gains after amelioration for the group with an eye difficulty and 90 or higher I.Q. scores. The investigator felt at least some of this gain should be attributed to visual correction or training. The study was conducted over a two-year period with the eye examination and correction or training occurring mid way. No additional reading training was provided for the group before or after treatment.

Eames (19:460-5) examined the effect of limited visual field upon learning, especially reading. Eames treated 26 subjects for limited visual fields. The researcher noted that a relationship existed between expanded visual field and school improvement.

Spache and Tillman (61:103) reviewed Taylor's (66) work with suppressed vision. Taylor reported, "Suppression occurs in six to seven per cent of a school population." (61:103) Suppression of the poorer eye resulted from hyperopia, unequal accommodative range, differences in acuity between two eyes, vergence difficulties, or aniseikonia according to Taylor. Complete suppression may improve reading. Partial suppression is more impairing than total suppression.

Park and Burri (46:535-46) attempted to determine whether reading difficulties were due to incomplete maturation of the "sensory-motor responses to visual stimuli." (46:535) A visual examination for eye defects was given to each of 225 unselected children from grades one through eight in the city schools of Chicago. Mental age and reading scores were obtained from the local school system. The investigators found various undesirable eye factors, lack of 20/20 visual acuity, poor fusion, inadequate stereopsis, low distance and near phorias, and poor duction to be more prevalent among younger children than older children. As children grew older the percentages of eye defects dropped appreciably. Park and Burri concluded that many "first and second graders who were tested showed a visual mechanism which was incompletely matured." (46:545) This immaturity was demonstrated through "the frequency of low visual acuity, poor fusion and stereopsis, low and unstable duction, and fusion amplitude as compared with children from the other grade levels." (46:545) The researchers noted that the visual defects were most noticeable for near-point.

Eames (17:10-6) provided data on the visual functioning of 350 poor readers of average intellect with a median age of 9.557 and grade level of 3.625. Eighty per cent of the sample were boys and 20 per cent were girls. It was Eames' purpose to provide data only, not conclusions, depicting poor readers. Eames reported his findings by category:

Refraction errors. Over one-half of the group had refraction errors over .50 diopters. Eames considered a refraction error in excess of .50 diopters as crucial.

Coordination of the eyes. Eames found only ten per cent of the sample lacked coordination at distance while over 50 per cent lacked coordination at near-point. Exophoria was the most common defect noted. Exophoria was noted to increase with age, suggesting the need for separate standards for the various age levels.

Fusion and Duction. One-third of the group failed the fusion test. Eames noted that fusion decreased with size of print and suggested any interpretation of fusion be interpreted in terms of size of print.

Central visual field. Eames noted a one-fourth contraction of both horizontal and vertical fields of vision among poor readers.

Park and Burri (45:292) reported the results of research conducted by Ames (1) on the effects of visual deficiency upon the speed of recognition of pictures or words. Ames concluded that speed of recognition was influenced by visual deficiencies.

Spache (60:616-18) investigated the reading ability of 23 children with strong eye preferences. The researcher noted that 43 per cent of the children read significantly better with their preferred eye. Spache noted no difference in reading speed or ability among 21 of the subjects who had differences in visual acuity between the two eyes when they read with the preferred eye alone or both eyes together. There was a notable drop in speed when the subjects attempted to read with the weaker eye alone.

Eames (21:700-2) explored the effect of correction for anisometropia on reading achievement of an experimental group of 25 anisometropes. The researcher used a control group with normal vision and normal reading ability. Eames noted substantial gains in reading achievement after correction of refractive errors in the experimental group. The examiner concluded that the effect of anisometropia on reading achievement was more profound than similar refractive errors in both eyes, regardless of type.

Young (68:257-64) reported that myopes were significantly better readers than hyperopes and in general better readers than emmetropes when measured in terms of their respective expectancies.

Kephart and Manas (39:36-39) found a relationship between visual skills and school achievement for a sample of kindergarten children.

Skeffington (56:1,755) reported pertinent research done by Harmon (32) with 160,000 school children. Harmon found that measurable ocular defects rose steadily from 20 per cent to 80 per cent between grades one and six.

Certain researchers have reported a relationship between reading and visual factors. Often the relationship was found to exist between visual factors in general, while at other times specific visual factors were involved. These relationships were found with both clinical and nonclinical populations. The degree of relationship varied from suggestive in studies where findings were reported in percentages to highly probable where complex statistical procedures were employed.

## STUDIES SUGGESTING NO RELATIONSHIP BETWEEN VISUAL DEFECTS AND READING ABILITY

While a number of researchers have reported positive correlations between deficient reading ability and visual disorders, other researchers failed to find such relationships. These latter researchers hasten to add, however, that in individual cases vision may well be a causal factor.

Witty and Kopel (69) reported on the relationship of heterophoria and reading disability among 100 third through sixth grade children with average ability in reading but who were functioning one semester or more below grade norms. A group of similar children with normal reading ability were used as a control group. The relationship between all muscle balance difficulties and reading ability, isolated or in total, demonstrated little positive relationship.

Spache (57:539-43) examined the relationship between eye preference and reading ability and visual acuity and reading ability. The investigator developed the Binocular Reading Test to measure eye preference and the degree of preference. Spache noted that strong eye preference during reading was an indication of other existing visual defects such as astigmatism, eye muscle imbalance, loss of acuity, and strabismus. Spache concluded that the reading ability of those with a marked eye preference could be seriously affected, especially if they tended to read with the less efficient eye. Spache's findings relative to acuity and reading ability were in agreement with other researchers and indicated no significant relationship.

Ball (2:173-8) reviewed the Michigan State University Reading Center records of 298 children referred over a 1½-year period for reading difficulties. Ball determined that 40.3 per cent of those children screened by the Bausch and Lomb School Vision Tester screening series failed. Because the Vision Tester screened only "distance visual acuity in each eye, plus lens test in each eye, distance phoria, and near phoria," the investigator concluded that "the true percentage of children with a possible visual disability would almost certainly be much higher than the already alarming 40.3 per cent." (2:176) Ball concluded that the researchers who attempt to correlate visual difficulties with reading inability have been for the most part unsuccessful. Ball felt the only conclusive finding was the consistently high percentage of children with visual defects. As a result, he recommended a complete visual analysis by a qualified vision specialist for all remedial readers.

Dalton (12:81-94) surveyed the visual functioning of 5,821 subjects in grades three through twelve with the Keystone Telebinocular test. Dalton observed that children with normal vision did no better than children with defective vision in general achievement or reading performance. The investigator concluded that "on the average, there was very little, if any, general relationship between normal or defective vision and scholastic achievement." (12:94)

Gates and Bond (28:450-6) explored the relationship of reading to handedness, eye dominance, visual acuity and all combinations of the three. The sample consisted of first grade children and the research design employed two sets of matched groups, the first for comparisons after "several years of school experience" and the second pair for comparisons during the initial stages of learning. The researchers found no relationship between the various factors or combinations of factors and reading achievement, word pronunciation, reversals, or visual perception. Gates and Bond concluded that their findings were consistent with those of Woody and Phillips, Gates, Kirk, Teegarden, and Witty and Kopel.

Eames (14:211-5) compared the ocular characteristics of a group of 114 disabled readers and 143 unselected school children. Eames reported that children with reading disability as a group tended to have "poorer vision, greater degrees of exophoria in distance and near vision, and lower directions." The researcher concluded that the differences between the two groups were too small to be significant. (14:212)

Witty (70:449-59) studied the relationship of poor reading to "reversals, to fusion difficulties, to muscle imbalance, and to mixed eye-hand dominance." (70:450) Witty's sample consisted of 100 children with average or above intelligence who scored lowest among 2,000 children on several standardized reading tests in grades three through six. A similar number of average readers matched for intelligence and chronological age were used as a comparison group. The researcher concluded that poor readers were none the worse visually than good readers. The better readers demonstrated slightly better vision in toto, moderately better for "slow fusion." (70:457) Witty found no "general factor contributing to poor reading." (70:456) Monroe, (43) from her investigations, concurred with Witty or his conclusions.

Shearer (54:47-52) used the Keystone telebinocular test to investigate the visual functioning of 220 elementary school students reading one or more years below grade level. Shearer found 54 per cent of the sample had sight difficulties and gave the following breakdown of difficulties: (54:47-52)

| | |
|---|---|
| Hypermotropia (over 1 prism Diopter) . . | 16% |
| Hyperopic astigmatism . . . . . | 3 |
| Myopia (over ½ D) . . . . . | 4 |
| Myopia astigmatism . . . . . | 3 |

| | |
|---|---|
| Vertical phorias (over 1 D) . . . . . | 1 |
| Esophoria (over 4 D) . . . . . | 2 |
| Exophoria (over 4 D) . . . . . | 3 |
| Exophoria at near . . . . . | 26 |
| Poor convergence . . . . . | 12 |
| Poor stereopsis and fusion ability . . | 10 |

Blake and Dearborn (7:83-8) reported on the visual defects of good and poor readers at the beginning of their freshman year in college. Results of ten diagnostic vision tests led the investigators to conclude that farsightedness was more common among poor readers. The researchers further concluded that poor readers demonstrated less binocular coordination, a relatively high percentage (26 per cent) of pseudo-myopia, and more frequent anisometropia than the control group. No single visual test or defect differentiated good from poor readers. Poor readers tended to have more, but not significantly more, visual defects than good readers.

Clark (10:530-38) analyzed the effect of binocular imbalance on the behavior of the eyes during reading. The subjects for his experiment were eleven university freshmen with near-point exophoria who were matched with eleven similar students possessing normal binocular balance. Eye movements during reading were recorded by a specially prepared camera developed by the investigator. Clark found no significant differences between groups in the number of fixations or regressions per line of print. Neither did the investigator note any significant difference in the duration or extent of divergent movements. The slight differences in divergent movements made by the exophoric group were noted by the researcher as a possible indicator of a source of additional fatigue and of notable value for remedial reading.

Jackson and Schye (36:33-5) compared the vision and reading scores of 640 high school freshmen. A 20/30 or poor vision score on the Snellen Chart test was considered a failure. Thirty-two per cent of the girls and 22 per cent of the boys failed to pass this criterion. Pupils with defective vision outperformed students with adequate vision. The investigators noted some of the methods used by students to compensate for their deficiencies in vision:

1. Changing seat position
2. Moving objects nearer to the eyes
3. Using a classmate's paper for a copy
4. Asking a classmate to read the material aloud
5. Squinting and straining for better focus
6. Twisting and turning the head to focus one eye
7. Seeking better lighting conditions

Stromberg (64:349-55) studied the binocular movements of the eyes of a group of fast and a group of slow college readers. Two types of material were read; first relatively simple three words to a line material; and

secondly, ten lines of prose from R. L. Stevenson's Kidnapped. Stromberg found no difference in the distribution of exophoria and esophoria among the populations of fast or slow readers or among any combination of individuals within either population.

Stromberg (63:70-8) investigated the relationship of visual acuity and ametropia to speed of reading with a group of fast and slow reading college sophomores and juniors at the University of Minnesota. Stromberg concluded there was no relationship between visual efficiency and reading ability that could not be accounted for by chance factors.

Swanson and Tiffin (65:433-48) examined the Betts Test of Visual Sensation and Perception for differentiating between good and poor first-year college readers. The researchers concluded there was no statistically significant difference between good and poor readers visually as evidenced by the Betts tests. No significant differences between groups were found for (1) far-point and near-point fusion, (2) lateral imbalance, (3) vertical imbalance, (4) stereopsis, (5) visual acuity, and (6) ametropia.

Imus, Rothney, and Bear (35:1-144) examined the relationship between various visual defects and reading performance of 636 freshmen at Dartmouth College in 1940. The experiment grew out of the need for answers to questions concerning the reading and visual proficiency of Dartmouth College students raised by the college faculty. The investigators found that ocular defects were no more common among deficient readers or students with poor grades than among the remainder of the population.

Fendrick (24:1-54) compared the visual characteristics of 64 reading disability cases with 64 subjects constituting a control group to note "the degree of disparity which might exist for the two reading populations with respect to various physiological measures of vision." (24:1) Fendrick found no difference between groups in refractive errors needing correction. Good readers receiving nonphonetic reading instruction had significantly better right, left, and binocular vision than poor readers with similar instruction. The between group difference was not significant for those subjects taught by the phonetic method. No significant difference for "lateral muscle-imbalance at distance or near fixation" was found. (24:47) A predominant eye or hand did not characterize any group. Seventy-five per cent of the good readers and fifty per cent of the poor readers in the nonphonetic group had normal vision. An examination with the Keystone Telebinocular tests of reading readiness of beginning readers confirmed right eye superiority of the nonphonetic group.

Betts and Austin (5:1-80) investigated the relationship between visual factors and achievement in reading based upon mental capacity. The sample consisted of 126 fifth grade children, the entire fifth grade population of Huntington, Pennsylvania. The researchers found no significant relationship between reading achievement and total visual functioning.

Robinson and Huelsman (49:31-63) investigated the relationship between visual efficiency and reading progress for 57 first, 53 fourth, and 52 seventh grade children from the University of Chicago Laboratory School. The investigators employed numerous tests of vision and reading and treated the results statistically whenever possible. The researchers concluded that visual standards set by commercial tests were unrealistic for first grade children. Individual visual tests demonstrated only a slight relationship with individual reading tests in grades four and seven. Binocular functioning was the only test distinguishing between good and poor readers in the fourth and seventh grades.

Schubert (51:16-7) reported the research conclusions of Goodsel (31) who investigated the relationship between reading ability and physical, mental, and personality traits. According to Schubert, Goodsell concluded that he had "failed to find a significant relationship between visual efficiency and ability in learning to read and comprehend." (51:17)

Park and Burri (45:290-9) reported the research results of McFarland, Knehr, and Berens (42) who found no correlation between binocular cooperation and phorias for clinical patients and a control group. Correlations between binocular cooperation or phorias and measures of reading efficiency were also found to be unrelated.

Seefelt (52:477-93) in his investigation of the effect of visual correction upon academic achievement reported no difference in post-corrective perfotmance.

Nadell, Waymouth, and Monroe (44:523-37) found no relationship between frequency of frequency of reading and refractive errors for 409 ninth and tenth grade students.

Edson, Bond, and Cook (22:451-57) investigated the relationship between various measures of silent reading ability and visual ability. The researchers concluded that reading achievement and vision ability were not significantly related.

Betts (4:172-202) from his experience in researching visual and reading factors concluded that although certain visual inefficiencies may hinder one child's reading, they may not hinder others. According to Betts, some children are quite able to compensate for their disability while others are not. Betts concluded that both types of children needed assistance.

In the first section studies dealing with various degrees of relationship between reading and visual factors were reviewed. In this section studies have been reviewed which appear to contradict those in the earlier section. Although a concise statement on the relationship or lack of relationship between vision and reading is still lacking, with certain qualifications to be set forth later, some directions are becoming apparent.

## STUDIES WITH COROLLARY SIGNIFICANCE

During the course of reviewing the research related to vision and reading, a few studies were uncovered which were seen as having corollary significance to the topic under study while not being specifically related. These studies because of their corollary interest are included under a separate section.

Eames (20:102-4) investigated the incidence of eye defects among boys and girls. The sample consisted of 443 subjects, 80 per cent boys and 20 per cent girls, of the Anglo-Saxon race. The data indicated that there was no parallel between visual defects and sex as had been found between reading ability and sex.

Skeffington (56:1,755) reported a pertinent conclusion from research conducted by Harmon. (32) Harmon found that measurable ocular defects rose steadily from 20 per cent to 80 per cent between grades one and six for a sample of 160,000 children.

Johnson (37:268-71) screened 16,675 subjects in grades one through twelve with a plus sphere lens to note the incidence of hyperopia. The investigator used a 1.5 screening lens for older children and a 1.75 lens for younger children. The researcher compared her results with those reported by the Massachusetts Department of Public Health and the developers of the Massachusetts Vision Test, who reported seven per cent of all school children examined to be farsighted with similar lens requirements. Johnson found only 1.5 per cent incidence of failure for the total group. A tendency for more younger than older children to fail the hyperopia test was also reported.

Skeffington (56:1,753-6) presented a strong argument for "learning lens" on all beginning readers. Skeffington presented evidence which indicated that the eyes were physiologically constructed for distance vision. Other research reported suggested that near-point vision in a contained environment produced an avoidance tendency in the nervous system. Such an avoidance tendency produced stress. Skeffington quoted Shipman on the effects of stress. "Stress brings up a construction of the perceptual fields, and the child observes less, sees less, remembers less, learns less, and becomes generally less efficient." (56:1,754) To neutralize this avoidance tendency, Skeffington suggested a

> convex spherical spectacle lens allowing the organism to continue at the near-centered visual task; but it provided satisfaction of the avoidance urge, that of avoiding, or getting away from, the containing task. Thus, the organism can achieve and avoid at the same time. (56:1,755)

Skeffington noted research reported by Harmon suggesting that 80 per cent of beginning sixth grade children have measurable ocular defects. Skeffington claimed the question is not whether we should put lenses on all beginning readers but rather "do we think it is necessary to protect the learning ability of every child." (56:1,755)

## REVIEWS OF RESEARCH RELATED TO VISION AND READING

A number of reviews have been reported which surveyed significant research on reading and attempted to organize the research and draw conclusions.

Robinson (40:7-31) examined the research related to vision and reading. The reviewer concluded that "regardless of age, level, or tests used, gross measures of visual acuity do not differentiate good readers from poor readers." (48:15) Robinson noted that among the refractive errors, hyperopia was found more often among poor readers and myopia among good readers, while astigmatism did not seem to be related to reading. The evidence from research on binocular coordination yielded only conflicting conclusions. Research in visual fields and with blind spots was inconclusive. Aniseikonia in amounts over one per cent were concluded to be a serious factor for deficient readers and correction was recommended.

Spache (58:229-38) compiled a comprehensive report of 50 separate research studies. Spache reached several general conclusions from this survey of the literature: (1) Visual defects do not differentiate good readers from poor readers. (2) Visual defects are a hindrance in individual cases and their correction an advantage. (3) Spache cited Witty and Kopel's (70) conclusion which suggested that visual defects may impede both good and poor readers. Because some particular defects may have more significance than others, Spache reviewed evidence concerning each individually:

Visual acuity. Generally insignificant differences were found between poor and good readers on all levels.

Refractive errors. Hyperopia seemed to be associated with less than normal readers; myopia with average or better readers; hyperopia and myopic astigmatism were found equally among good and poor readers.

Eye muscle imbalance. Muscle imbalance, especially exophoria, are associated with poor reading progress.

Interpupillary distance. Spache cited Betts who noted the greatest gains (1.9mm) in interpupillary growth to take place in first grade. Betts concluded that beginning reading instruction during this stage of maximum interpupillary growth would cause additional stress on the beginning reader and may affect reading progress in early grades.

Stereopsis and Binocular Coordination. "May not be required per sé but the degree of visual fusion necessary for its achievement contributed to the acquiring of good reading habits" according to Spache. (58:235) Loss of binocular coordination and stereopsis may result in still further losses in other visual functions such as acuity and eye muscle imbalance.

Aniseikonia. Aniseikonia seemed to hinder reading ability of younger children, but adults seemed to compensate for the difficulty.

Visual field. Evidence indicated a narrow visual field may hinder reading progress. Peripheral vision was seen as especially important for speed of reading.

Schubert (51:16-17) pointed out a number of reasons for the disparate findings of the various researchers in the area of vision as it related to reading. The reporter pointed to such factors as orientation or training of the researchers which often result in an emphasis on one area while others are minimized; measuring devices that range from retinoscopes to Snellen charts; differences in the ages of the children studied and compared; lack of an agreed upon definition of reading disability; and tolerances of the individual child. Schubert noted only one area of total agreement which was the need for a complete visual evaluation of every deficient reader.

Spache (59:04-08) indicated that research reports are conflicting because (1) a variety of tests have been used by investigators, (2) vision tests are generally low in reliability, (3) many researchers ignore the age of their sample or the developmental nature of vision, (4) many researchers have an atomistic concept of vision so they measure each function separately rather than as interrelationships, and (5) many tests have absolute standards that have been arbitrarily set and do not allow for human variance. Concerning the final point, Spache believed that a function can vary as long as it does not interfere with other functions.

Bing (6:454-63) in her review of the research related to visual functions and reading achievement noted that visual defects may be the cause, a contributing factor, or unrelated to reading performance. Bing attributed the diversity of findings to uncontrolled age differences and testing situations, inadequate and nonstandardized testing procedures, the lack of agreement over the definitions of such fundamental words as reading disability, visual defects, and adequate vision. Also noted was the failure to evaluate the various visual factors in interaction.

Eames noted that vision was historically the first suspect of reading difficulties. Today, according to Eames, it has been statistically demonstrated that,

> defective visual acuity is not much more frequent among reading failures than among nonfailures, although individual cases occur in which failure is definitely the result of impaired vision. (18:427)

Bond and Tinker from their review of survey studies of visual deficiencies reported that most studies revealed a large number of visual problems among school population. Usually no significant relationship was found between vision difficulties and reading problems. (8:86)

Friedenberg in his review of the research reported correlation coefficients from .0 to .95 between vision and school achievement. He concluded that it was difficult to determine the cause of reading difficulties and to estimate their etiology. (27:32-3)

Staiger reporting on Robinson's study of why pupils fail in reading concluded that Robinson demonstrated that the retarded reader could not be characterized by any one deficiency. (62:41-43)

Harris (33:231-9) from his examination of the research reported that he believed Park and Burri, Eames, and Robinson and Huelsman demonstrated a relationship between certain visual dysfunctions and reading achievement. The most notable visual dysfunctions related to reading achievement were "poor near-point acuity and poor eye-muscle balance with accompanying deficiencies in fusion and depth perception." (18:235)

Roswell and Natchez (50:8-9) believed the research attempting to associate vision difficulties with reading problems to be indecisive.

Tramonti (67:543-9) indicated that there were many reasons for inadequate school achievement. The reporter concluded that the main reason for inadequate achievement was intellectual subnormality. Visual factors were seen by the reporter only as a possible contributing factor.

Pollack and Piekarz (47:17-9) concluded from their survey of the research that a relationship existed between nearsightedness and academic success.

The reviews of research reported here suggest various relationships between reading and vision. The conclusions seem to be flavored by the articles reviewed and the particular orientation of the reviewer. Those reviewers examining studies which explored the relationship between reading ability and specific visual functions tended to find more relationship than those examining only surveys. As one might expect, those reviewers with substantial academic training and background in the area of vision noted more relationships between reading and visual factors than those lacking training in vision.

## LIMITATIONS TO THE CONCLUSIONS

A single reading of the research related to vision is likely to leave the reviewer bewildered. The technical vocabulary is confusing to say nothing of the lack of control over internal and external validity variables. A perusal reading, however, allows certain generalizations to be made with some degree of certainty. The degree of certainty or application of the findings will depend upon the situation in which one wishes to apply them. For example, generalizations will be more valid when applied to groups rather than individuals and when looked at as precipitating rather than causal factors. The reader should be aware of the following limitations of the research reviewed. This awareness will bring forth one of the more striking conclusions in this review--that little common ground exists for comparing studies with seemingly corresponding purposes.

The various reading and visual tests administered to groups of deficient and normal readers do not agree as to subtest inclusions. Writers generally do not make this information known in their reports.

In reading the separate research reports, it is often not possible to determine the appropriate context in which a researcher is using a technical word. The glossary of vision terms was developed as an attempt to standardize word or phrase meaning for reliable interpretation.

Measurement of defects in terms of instruments used and degree of dysfunction required for disorder also attributes to the dilemma of generalizability. (13, 17, 37) Instruments vary in sophistication from the Snellen Chart to the office equipment of the optometrist and ophthalmologist. Degree of dysfunction necessary to be considered defective varied from four-eight prism diopters for fusion. For far-sightedness, Johnson (37) used a 1.50 screening lens for children and 1.75 for adults while Eames (17) said anything over 1.0 prism diopters is worthy of attention. In general, optometrists maintained the most demanding criteria of normalacy. It appeared as though the patient would have to prove he had normal vision in the optometrist's office, while in the ophthalmologist's office he would have to prove his vision was defective.

Another factor influencing the generalizability of various research reports is the method of sampling. In many cases, how the sample was obtained was not reported. In others it was reported as being obtained from classrooms or clinics. A few samples were noted as being "unselected" which meant "random" to those researchers. Samples of normal readers obtained from classrooms as unselected samples were often compared to an unselected sample of deficient readers in clinical or remedial settings. Not one study contained randomly selected groups of normal and defective readers from a sufficiently large population to satisfy an external validity criterion.

Many researchers ignored the age of their samples. It was quite common to find an age spread of five years or more in a single study. If vision is developmental, correlation techniques are likely to result in high correlations for homogeneous groups and low for heterogeneous groups.

Some researchers did not take note of the developmental nature of vision. This is particularly true of those researchers investigating relationships with kindergarten and first grade children. Measuring certain functions, such as hyperphoria, before maturation will produce spuriously high correlations not found by similar research on the same sample a year or two later.

Atomistic research or measuring visual functions separately rather than in interaction to note degree of interreletionship is also a source of confusion. It was often not clear whether the researcher was measuring total vision or a single vision aspect in relation to reading. High, low, or humorous relationships often result. When Farris (23) combined the total vision scores for the defective group, he found that the members of the defective group were better readers. Unless one knew that a vast number of myopics were present in the defective group, the true meaning may be obscure to the reader. Single vision seems to demonstrate consistently higher relationships to reading than does total visual defects.

Many of the tests used in the research projects have questionable reliability according to Spache. (59) Spache noted that many of the tests used have arbitrarily established cut-off points for pass or fail. If what Spache says is accurate, the selection of tests will influence correlation and the impending conclusions.

There are a number of published research reviews available to the reader. Upon reading these reviews, the conclusion one reaches is that reviewers seldom

agree completely on what the research suggests. An examination of the various bibliographies gives a clue as to why this conclusion seems to predominate. The references reviewed are strikingly different and seem to correspond to the orientation of the reviewer. Generally, it appears that what is considered significant research worthy of review and upon which conclusions are later drawn seems to depend upon the orientation of the reviewer.

Most results are only suggestive and are meant to be no more by their investigators. Eames, (17) for example, reported his findings as characteristic of deficient readers with visual defects. Eames drew no conclusions but added to the literature basic information that might be useful to future investigators. Eames realized that few studies approach definitiveness by themselves and that meaning evolves from many carefully planned and executed studies over cross-sections of the population.

Methods of reporting data are not standardized leading to further confusion for the reviewer. One researcher reports his findings in percentages, another as a correlation coefficient, another as a test of significance between two groups, another in terms of good readers, while still another reports his results in terms of poor readers.

Qualified words such as good, poor, some success, and generally are used all too often. Little meaning can be obtained from research results reported in vague terms.

The meaning attached to the words deficient reader also changes from research report to research report. In most studies the words are not defined. When they have been defined, they have meant deficiency in speed, specific skills, or below grade level or expectancy levels. Grade level or expectancy level were never defined.

Finally, correlation itself is a statistical technique designed to demonstrate relationship, not cause and effect. Investigators occasionally lose sight of this fact when drawing their conclusions, and as a result, attach more significance than is warranted to their findings.

## CONCLUSIONS AND DISCUSSION

Within the limitations placed upon this review the following conclusions and comments seem tenable.

Both good and poor readers have an abundance of eye defects. As a result, comparisons between good and poor readers may be hindered by the fact that both groups are deficient in vision. What is needed is a comparison group never exposed to reading. Such a group would, however, be difficult to obtain.

Visual defects in terms of the number of children affected increased with years in school or chronological age. Because a comparative group never exposed to reading or to school is lacking, it is difficult to determine if the increase in visual defects is associated with school or would naturally occur with chronological age. Ophthalmologists claim the eye is physiologically mature at about age five.

It is possible that natural deterioration takes place after that time whether or not the child is exposed to reading.

Visual defects may not cause reading disabilities per sé but may impede reading development. Although no direct relationship has been demonstrated between reading deficiencies and visual defects, it seems defensible to suggest that any visual defect singularly or in combination may inhibit reading development. This would seem to be more true during the period of initial learning.

Individual differences in compensation ability for stresses and strains seem to enable certain children with visual defects to succeed while others fail. For this reason children need complete visual examinations and immediate attention to visual dysfunctions. Because there presently is no way of determining which children will be influenced by visual defects, correction or training must be provided wherever deficiencies are found.

Early identification and correction of visual deficiencies followed by intensive remedial training in deficient abilities seem to result in easier as well as earlier realization of skill expectancy. Corrected visual defects without corresponding reading instruction does not appear to result in any appreciable reading gains.

Various structural defects in vision may operate to produce retardation in reading. A number of investigators have attempted to demonstrate such relationships. For the most part, these structural defects serve as initial handicaps which are surmountable by many children but faltering to others. The conclusions are categorized and reported by structural defect.

Acuity. Research indicated little or no relationship between visual acuity and reading ability.

Refractive errors.

Hyperopia. A high relationship existed between hyperopia and reading deficiencies across most age and grade levels.

Myopia. A relationship existed between myopia and average or above average reading ability.

Astigmatism. It is distributed equally among good and poor readers.

Fusion. Good fusion was more often found to be associated with successful reading than unsuccessful reading.

Stereopsis. Stereopsis was associated with fusion and therefore associated with successful reading. Stereopsis was not considered necessary for reading except as it was necessary for fusion.

Muscle Balance or Phorias

Phorias. Phorias in general did not seem to be associated with good or poor readers.

Exophoria. The turning outward of the eyes during reading was associated equally with good and poor reading performance. This finding was not consistent with the findings of another reviewer. (58)

Esophoria. The turning of the eyes inward during reading was associated equally with good and poor reading performance.

Aniseikonia. A slight relationship between aniseikonia and reading deficiences existed for young children. This relationship disappeared as they approached adulthood.

Ductions. A relationship between duction power and reading ability existed.

Dominance. Hand and eye dominance was equally distributed among good and poor readers.

Visual Field and School Improvement. Visual field may affect speed of reading but does not seem to have any other direct effects upon reading.

Suppression. Partial suppression of vision could be a factor in reading deficiencies if the reader attempted to read with the suppressed eye or alternate back and forth between eyes. Total suppression of one eye may improve reading ability. Suppression may have more diagnostic value than influence upon reading. Suppression resulted from hyperopia, unequal accommodative range, differences in acuity between the two eyes, vergence difficulties, or aniseikonia.

Eye Defects in General. When total visual defects were correlated with reading deficiency, no relationship between the two factors existed. Since most investigators tend to include a test for myopia in their battery of vision tests, this relationship may not be accurate, however. Myopia appeared more frequently among good readers than poor readers. When all visual skills were considered in total, myopia may have caused the insignificance demonstrated between reading and other visual defects.

Growth in Reading After Visual Corrections. Reading growth after visual correction is likely to be dynamic with expectancy approximations if the following conditions exist: (1) the child is young, (2) the child has average intelligence, (3) the defect is diagnosed and treated or corrected early, and (4) the child is provided with intensive remedial instruction.

Generally, the conclusions reached in this review agree with and are included among those reported by other reviewers. One interesting generalization not reported by other reviewers can be made. Ophthalmologists and optometrists with their specialized training tend to see the research suggesting more relationships between visual defects and reading deficiencies than the reading educator who has less formal training in the area of vision. This probably reflects one or a combination of the following: depth of understanding, professional orientation, reference sampling, and reviewer bias. It is not clear which of these factors exerts the most influence in biasing the reviewers. What is evident, however, is that the reader should take into consideration factors likely to influence the reviewer's conclusions when attempting to read and evaluate the available evidence on vision and reading.

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## GLOSSARY

Accommodation. Ocular adjustments of focus for maximum clarity at any distance.

Acuity. The ability of the unaided eye to see clearly an object focused upon when given adequate illumination. Usually measured in terms of the Snellen letter chart.

Alternating Squint. The suppression or suspension of vision and a turning of one eye during the visual task. Sometimes referred to as alternating strabismus or alternating vision.

Amblyopia. Reduction in visual acuity without an apparent structural defect or disease accountable for the reduction. Refraction does not raise vision to normal but may enhance focusing and relieve strain, but will not increase sensitivity. Usually occurs from fatigue or neglect.

Ametropia. A general term applied to an eye condition where there is an error of refraction. Simply stated, it means imperfect focus. Antonym: emmetropia

Aniseikonia. Inequality in size of the images being received by the two eyes; a difference between the way the two eyes perceive size.

Anisometropia. A refraction difference between the two eyes. Both may be hyperopic or myopic with one eye demonstrating more error than the other. If one eye is hyperopic and the other myopic, the condition is called antimetropia.

Astigmatism. Blurred vision as a result of light rays from different planes in the eye failing to come to the same focus.

Binocular Vision. Pertaining to the use of both eyes simultaneously in contributing to visual perception.

Brain. A control center for sensory perception.

Ciliary Compensation. Accommodation brought about ciliary muscle action which is exerted to bring the hypermetropic eye into focus.

Ciliary Muscles. The intrinsic focusing muscles of the eyes.

Convergence. The turning inward of the visual axes of the eyes.

Cornea. Clear curved window in front of iris and pupil of the eye.

Diopters. Units of focal length used to designate the refractive power of a lens or an optical system. The number of diopters is equal to the reciprocal of the focal length in meters.

Diplopia. Double vision.

Divergence. The turning outward from the visual axes of the eyes.

Ductions. Refers to the power or ability of the various pairs of extrinsic ocular muscles to perform their function adequately. Duction tests are used to determine muscle power.

Emmetropia. Perfect focus for distance when the eyes are at rest. No need for an accommodative response for sharp focus when the eyes are at rest.

Esophoria. The tendency for the eyes to turn inward.

Exophoria. The tendency for the eyes to turn outward.

External Strabismus. Walleyedness; also referred to as divergent strabismus.

Extrinsic Muscles. The external muscles controlling the movements of the eyes.

Functional Optometrists. Optometrists who are specifically attempting to identify and teach visual skills.

Fusion. The ability of the individual to combine mentally the picture from one eye with that from the other, producing singular, binocular vision. (17) A condition in which two images are sent back to the brain and are properly blended in one mental image.

Glasses or Lenses. Devices designed to bend light rays sufficiently to make up for excess or deficient refraction of the unaided eye.

Heterophoria. Imperfect eye condition of latent muscle imbalance.

Hypermetropia. When the incoming light rays fail to focus before reaching the retina. The hyperope may see well at a distance but not at nearpoint. Synonym: farsightedness, hyperopia.

Hyperphoria. Condition in which one of the eyes tends to turn upward stressing fusion.

Hypophoria. Condition in which one of the eyes is turned downward stressing fusion.

Interfixation Movements. Movements of the eyes between points of fixation.

Interlinear Movements. Movements between successive lines of print such as in a return sweep.

Internal Strabismus. Cross eyedness; also referred to as convergent strabismus.

Macula. The most highly sensitive area of the retina where seeing of fine detail is accomplished. Both eyes have a macular area.

Monocular Vision. Seeing with only one eye. As a result, three-dimensional depth perception is lost.

Muscles of the eye. Mechanism or contractile organs reacting to sensory stimulation that move the eyes.

Musculature. Refers to muscles controlling the movements of the eyes.

Myopia. When the rays focus before reaching the retinae. The myope sees well at near but not at a distance. Synonym: nearsightedness.

Orthophoria. Perfect eye coordination for convergence.

Orthophoric. Perfectly coordinated eyes.

Permanent Cramp. A state of hypertension which results from prolonged periods of compensation for farsightedness (pseudo-myopia). Characterized by an inability to bring distant objects (ten feet) into clear focus. (7)

Phorias. The amount of deviation of the eyes from the object of regard when there is no fusion stimulus.

Prism Diopter. A unit of prism power used in measurement. Specifies the amount of the deviation of light rays.

Pseudo-Myopia. A condition that arises when compensatory action of the focusing (ciliary) muscles is continued for prolonged periods. (7)

Refraction. Involves changing the direction of light entering the eye as a result of having it first pass through another medium such as a lens.

Refractive Error. Those errors of vision that can be corrected by lenses such as myopia, hyperopia, and astigmatism. (62) Result of faulty focus of the light rays that enter the eyes.

Retina. The layers of the eye containing the visually sensitive receptors.

Sight. The ability to recognize light, light contrasts, and light patterns.

Stereopsis. Refers to the ability to sense depth and is dependent upon the use of two eyes.

Strabismus. Muscular imbalance of one or both eyes or lack of binocular coordination. When the eyes are at rest, one or both of the visual axes deviate from parallelism. Presents a blurred image to the subject. Two types are exophoria and esophoria.

Suspenopsia. The suspension of vision in one voluntary eye when attention is directed toward an object in the field of the other eye. Sometimes referred to as alternating vision.

Unselected Group. Refers to a group whose members were selected at random from a larger parent population.

Vertical Imbalance. One of the eyes deviates upwards or downwards. Hyperphoria, one eye upward; hypophoria, one eye downward.

TABLE 1

The following table is an attempt to present the various studies in capsule form. The reader should be extremely cautious in generalizing from this compilation. The compilation is included to give the reader a brief overview of the aspects of vision investigated to determine their relationship to reading. The extent to which each aspect of vision was investigated and to some degree the strength of each conclusion can be judged from this compilation.

Table 1. SUMMARY OF THE RELATIONSHIP OF VARIOUS VISUAL DEFECTS TO READING INABILITY* **

| | Refractive Errors | | | | |
|---|---|---|---|---|---|
| Acuity | Hyperopia | Myopia | Astigmatism | Ametropia | Fusion |
| R 45 | R 7 | NR 65 | R 3 | R 45 | R 45 |
| R 61 | R 15 | NR 23 | NR 23 | R 24 | R 61 |
| R 46 | R 24 | NR 68 | | R 21 | R 15 |
| R 60 | R 23 | | | NR 63 | R 46 |
| NR 57 | R 29 | | | NR 65 | NR 70 |
| NR 28 | NR 65 | | | NR 44 | |
| NR 36 | | | | | |
| NR 63 | | | | | |
| NR 65 | | | | | |

* Numbers correspond to bibliographical references

**R indicates a relationship between visual defect(s) and reading inability

NR indicates no relationship between visual defect(s) and reading inability

Table 1. (continued)

| Phorias | Muscle Balance: Exophoria | Esophoria | Aniseikonia | Ductions | Dominance |
|---|---|---|---|---|---|
| R 45 | R 15 | NR 64 | R 13 | R 45 | R 15 |
| R 61 | NR 10 | | | R 31 | R 29 |
| R 46 | NR 64 | | | R 46 | NR 28 |
| NR 42 | | | | | NR 70 |
| | | | | | NR 24 |

| Muscle Balance |
|---|
| R 53 |
| NR 69 |
| NR 70 |
| NR 65 |
| NR 24 |

| Binocular Incoordination |
|---|
| R 7 |
| R 49 |
| R 3 |

| Visual Field and School Improvement | Suppression | Eye Defects in General | Stereopsis | Growth in Reading After Correction |
|---|---|---|---|---|
| R 19 | R 61 | R 40 | R 45 | Growth 30 |
| | | R 39 | NR 65 | Growth 40 |
| | | R 45 | | Growth 21 |
| | | NR 23 | | Growth 16 |
| | | NR 22 | | |
| | | NR 51 | | No Growth 52 |
| | | NR 49 | | No Growth 16 |
| | | NR 5 | | |
| | | NR 35 | | |
| | | NR 7 | | |
| | | NR 43 | | |
| | | NR 70 | | |
| | | NR 14 | | |
| | | NR 12 | | |

Table 1. (continued)

| Lack of Phonetic Reading Instruction | Strabismus | Convergence | Speed of Recognition |
|---|---|---|---|
| NR 24 | NR 23 | R 34 | R 42 |